# NONPOINT SOURCE WATER QUALITY IMPACTS AT SACRAMENTO NATIONAL WILDLIFE REFUGE, WILLOWS, CALIFORNIA

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SUMMARY

The purpose of this investigation is to evaluate potential water quality impacts caused by nonpoint source agricultural drainage entering Sacramento National Wildlife Refuge (NWR) at Willows, California. The Central Valley of California provides vital wetland habitat for over 60% of the Pacific Flyway's total waterfowl population, and the Sacramento NWR is one of three federal refuges that attracts these migratory birds in the Colusa Basin of the Sacramento Valley. The U.S. Fish and Wildlife Service (USFWS) utilizes two water sources to maintain wetlands at this facility. The Glenn Colusa Irrigation District (GCID) diverts Sacramento River water into the Glenn Colusa Canal through the federal Central Valley Project and delivers fresh water to the refuge from this system through a contractual agreement with the USFWS. Agricultural return flows are diverted from Logan Creek to meet the firm water supply needs for seasonal marsh management and permanent ponds.

Agricultural drainage from intensive rice production and other agricultural crops upstream of the refuge may potentially threaten the beneficial use of this water for wildlife habitat. Trace element concentrations in drainage water evaporation ponds have resulted in toxic effects on wildlife populations in the San Joaquin Valley and Tulare Basin of California. Historical data gathered on the west side of the Sacramento Valley suggested elevated levels of selenium in fish and water samples, and past monitoring has linked rice herbicides to fish kills in agricultural drains of the Sacramento Valley.

A reconnaissance level water quality monitoring program was established to characterize water inflows to the Sacramento NWR. The results of this investigation show that mineral and trace element concentrations from agricultural return flows do not appear to be limiting factors in the beneficial use of water for wildlife habitat at this site. Selenium levels ranged from 0.1 - 1.2 µg/L with a median selenium concentration of 0.4 µg/L, which is well below the Environmental Protection Agency's 5 µg/L criterion for the protection of freshwater aquatic life, and the 2 µg/L guideline utilized by the USFWS in the management of the federal refuges. Lead concentrations of 5 - 22 µg/L exceeded the 0.99 µg/L criterion for freshwater aquatic life in four samples collected from Logan Creek at

the refuge boundary. The source of this lead is unknown, but it is unlikely that agricultural drainage is the source.

Sediment trace element chemistry was evaluated at four sites and compared to natural background levels for California and the western United States. Copper, nickel, and chromium were all present in sediment at levels above what is expected in natural California soils.

Nutrient rich water from agricultural fertilizer runoff and the Willows sewage treatment plant have been identified by refuge personnel as potential links to the avian botulism problem at the refuge. Nutrient levels measured in the agricultural drains were very low. However, the limited data collected in this survey suggest ammonia concentrations in treatment plant discharges to Logan Creek that are significantly elevated to cause toxicity to fish.

Agricultural drainage entering the refuge was monitored for thirty-three pesticides that represent the agrichemical use on crops grown upstream of the refuge during this survey. Three thiocarbamate compounds were the only agrichemicals detected in the water samples. The herbicide EPTC (Eptam ®) was detected in two samples at 0.8 and 3.3 µg/L. The potential effect of intermittant exposure of wildlife to EPTC are unknown, as no protective guidelines have been established for this compound. The rice herbicide thiobencarb was detected in two of fifteen samples at levels well below the California Department of Fish and Game's (CDFG) recommended guideline of 24 µg/L. The rice herbicide molinate was routinely detected in every sample with a range of 3 - 92 µg/L. One sample exceeded the 90 µg/L recommended level set by CDFG. The results of this reconnaissance level pesticide monitoring signal the potential short term intermittant exposure of wildlife to herbicides from agricultural return flows draining into the refuge.

## RECOMMENDATIONS

1. The full extent of short term intermittant exposure of wildlife to herbicide concentrations in agricultural drainage needs to be determined. An in-stream biotoxicity testing study should be considered to evaluate impacts on freshwater organisms.

2. The pesticide discharges in this survey focused on the rice herbicide runoff season, as rice is the major crop grown upstream of the refuge. The detection of Eptam that is not used on rice suggests the need for pesticide monitoring throughout the irrigation season. Future monitoring programs should also evaluate organochlorine compounds in drain sediment.

3. Glenn Colusa Canal water supplies were not evaluated for organic chemicals. Future water quality monitoring programs at the refuge should include this major water supply, as refuge personnel have expressed concern with a potential decline in Sacramento River water quality.

4. The City of Willows Wastewater Treatment Plant discharge to Logan Creek is regulated by a National Pollutant Discharge Elimination System permit. This water quality permit is currently being updated by Regional Board staff. A revised monitoring program that includes in-stream biotoxicity testing is under consideration. The new permit should also consider receiving water limits for ammonia which ensure protection of the freshwater aquatic resources.

## LOCATION

Sacramento National Wildlife Refuge (NWR) was established in 1937 with funds from the Emergency Conservation Act of 1933. The 10,775 acre refuge is located in the lower Logan Creek watershed of the Colusa Basin five miles south of Willows near the center of the Sacramento Valley in Glenn and Colusa counties (Fig. 1). Sacramento NWR is one of three federal refuges encompassing 20,450 acres in the 1,700 square mile Colusa Basin. The purpose of the refuge is to provide food and resting areas for migratory waterfowl and breeding grounds for resident wildlife species, and to reduce waterfowl crop depradation on neighboring agricultural lands. There are also numerous private duck clubs within the Colusa Basin that utilize irrigation return flows to provide approximately 24,000 acres of seasonal wetlands for waterfowl.

## LAND USE

Land use within the refuge includes seasonally flooded marsh habitat, permanent ponds, upland habitat, and waterfowl food production including rice, and water grass (wild millet). Water is applied to ponds August through October to provide seasonal wetlands for migratory birds which winter in the Sacramento Valley. Seasonal wetlands are drained in April to germinate waterfowl food plants for the following season.

The headwaters of the 155 square mile Logan Creek watershed are located at 1200 feet elevation in the northern California Coastal Range west of the refuge. Vegetation in the upper watershed is primarily annual grasses, oaks, shrubs, and digger pine. Land use in the foothills is limited to cattle grazing, watershed, and wildlife habitat. Logan Creek drops down to the lower elevations of the Sacramento Valley through dissected terraces and Logan Ridge. The stream channel crosses the Tehama - Colusa Canal and enters the irrigated lands of the GCID. Rice production accounts for three-fourths of the water use in this district. Rice fields are flooded throughout the growing season with near continuous spill of water from the rice checks.

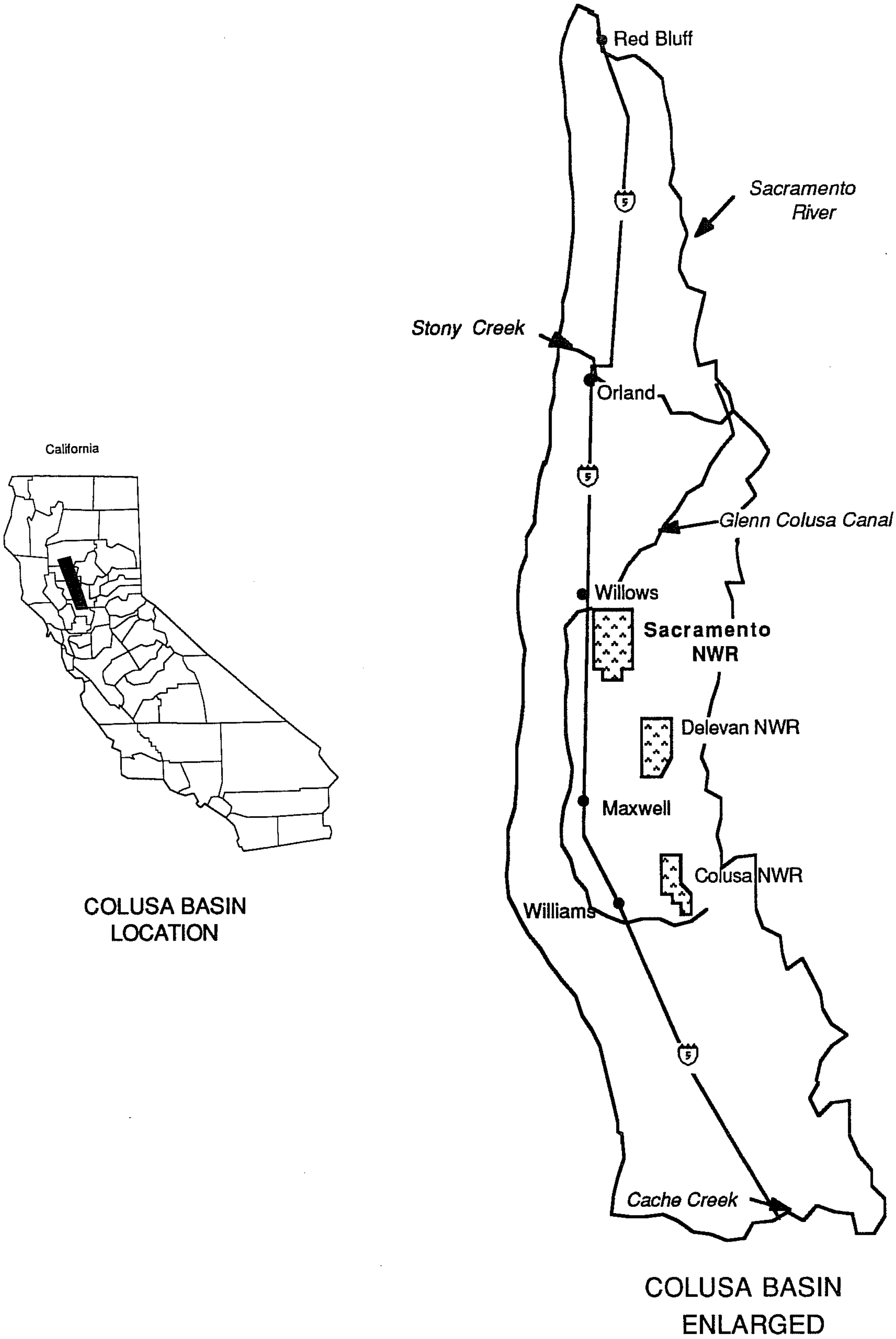



Figure 1. Location Map

Some drainwater is recycled through gravity diversions and drain pumps. Field drains discharge to local streams and agricultural drains that are tributary to the regional Colusa Basin Drain (CBD). Runoff from flooded rice fields is the major source of irrigation return flow delivered to the refuge from Logan Creek. The other crops grown upstream of the refuge during the 1987 season included corn, alfalfa, sugarbeets, wheat, prunes, and limited plantings of tomatoes and sunflowers (Fig. 2).

## WATER SUPPLY

The hydrologic system that supplies water to Sacramento NWR is shown in Figure 3. The main source of water to the refuge is surface supply delivered by the federal Central Valley Project. The GCID delivers water to 140,000 acres of cropland and to the Sacramento NWR. Water is diverted from the Sacramento River at Hamilton City into the 65 mile long Glenn Colusa Canal (GCC) and distributed to growers and refuge lands via 420 miles of irrigation laterals. The average annual amount of water delivered to the refuge from 1974 to 1980 was 43,029 acre feet (BOR, 1986). Actual water available for use on the refuge was less due to conveyance losses. The 26.2 Lateral of the GCC supplied an average water delivery of 20,772 acre feet under Contract 14-16-001-78021. GCID may also deliver water to the refuge from Stony Creek through a 10,000 acre feet allotment. The Bureau of Reclamation may provide this water from Stony Creek or Sacramento River diversions to the Tehama Colusa Canal. Water discharged from the refuge and surrounding agricultural land eventually flows into the Colusa Basin Drain (CBD). The CBD is the largest single source of agricultural wastewater discharge into the Sacramento River.

Agricultural return flows are diverted from Logan Creek to provide an average refuge water supplement of 16,440 acre feet per year. The Logan Creek watershed is the source of an additional 5000 - 12000 acre feet of direct tributary inflow. The refuge has appropriative rights to the Logan Creek water to supply 4575 acres of wetlands habitat.

Ground water has not been used as a refuge water supply. There is one developed well on the refuge, but low yields and high pumping costs have precluded its use.

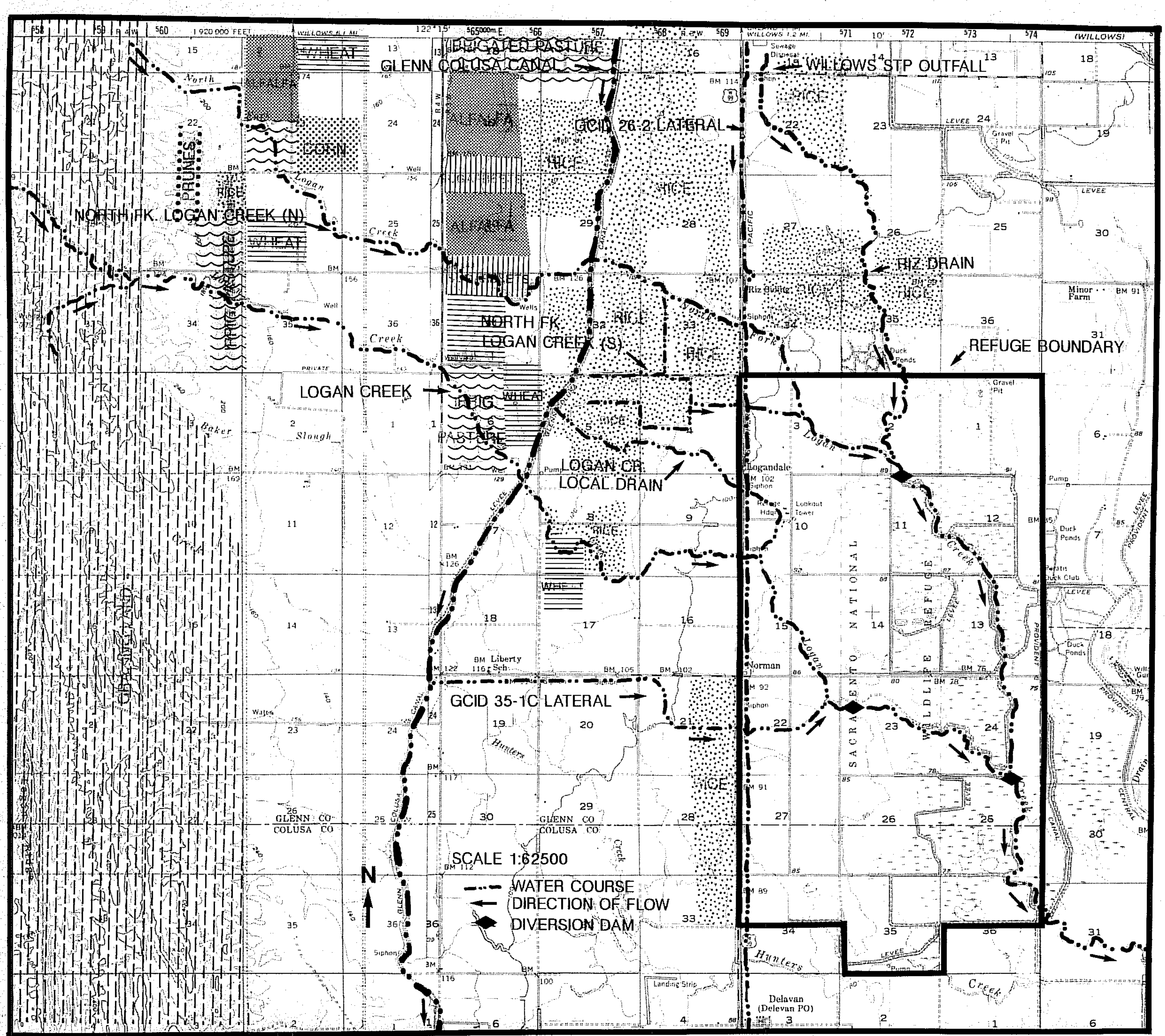



Fig. 2 Agricultural Land Use Upstream of Sacramento NWR - 1987

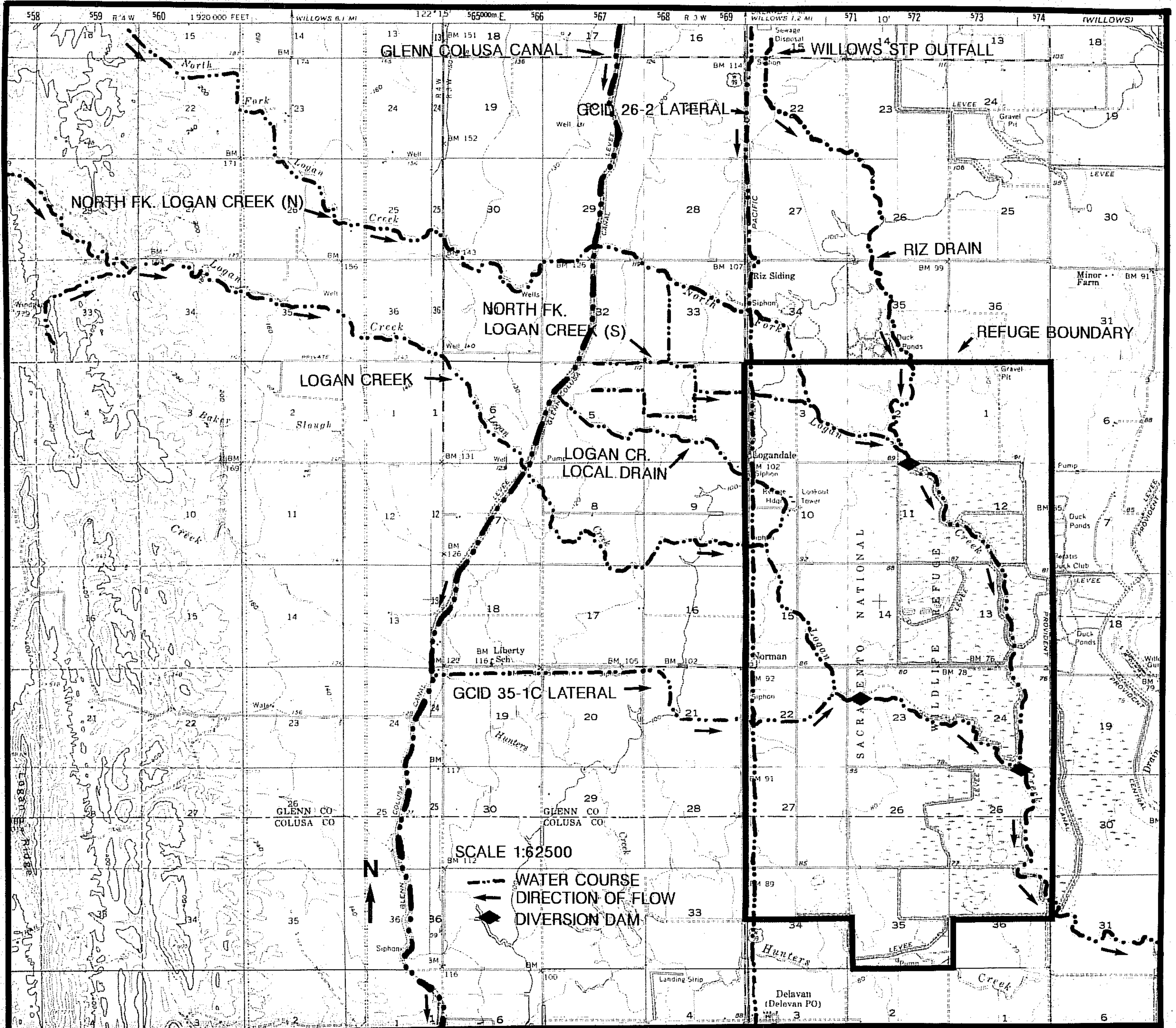



Fig. 3. Hydrologic System in the Vicinity of Sacramento NWR

## WILDLIFE

The Central Valley of California historically included up to five million acres of grasslands, seasonal marshes, and swamp. Today most of these wetlands have been drained and converted to agricultural and urban development. The valley continues to be a major wintering area for approximately sixty percent of the total waterfowl population of the Pacific Flyway. Sacramento NWR supports a winter peak population of over 500,000 ducks and 300,000 geese. Resident and migrant species which may be impacted by a water quality impairment are identified in Table 1.

Table 1. Wildlife Resources at Sacramento National Wildlife Refuge.

| DUCKS | SHORE/WADING BIRDS | UPLAND GAME |
|---|---|---|
| Hooded Merganser | Western Grebe | Ring-neck Pheasant |
| Mallard | Eared Grebe | Rock Dove |
| Gadwall | Pied-billed Grebe | Mourning Dove |
| European Wigeon | Double-crested Cormoran | California Quail |
| American Wigeon | White Pelican | **RAPTORIAL BIRDS** |
| Green-winged Teal | American Bittern | Turkey Vulture |
| Cinnamon Teal | Least Bittern | Peregrine Falcon |
| Blue-winged Teal | Great Blue Heron | Sharp-shinned Hawk |
| Northern Shoveler | Great Egret | Rough-legged Hawk |
| Pintail | Snowy Egret | Great Horned Owl |
| Wood Duck | Green-backed Heron | Black-shouldered Kite |
| Redhead | Virginia Rail | Cooper's Hawk |
| Canvasback | Sora | American Kestrel |
| Ruddy Duck | Common Gallinule | Red Shouldered Hawk |
| Ring-necked Duck | Ring-billed Gull | Northern Harrier |
| Common Goldeneye | Caspian Tern | Red-tailed Hawk |
| Greater Scaup | Forester's Tern | Barn Owl |
| Lesser Scaup | Black Tern | Golden Eagle |
| Bufflehead | Wilson's Phalarope | Bald Eagle |
| Common Merganser | American Avocet | **FISH** |
| **GEESE AND SWANS** | Black-necked Stilt | Steelhead |
| Snow Goose | Common Snipe | White Catfish |
| Ross' Goose | Long-billed Dowitcher | Chinook Salmon |
| White-fronted Goose | Least Sandpiper | White Crappie |
| Canada Goose | Dunlin | Largemouth Bass |
| Cackling Canada | Western Sandpiper | Carp |
| Lesser Canada Goose | Greater Yellowlegs | **FURBEARERS** |
| Tundra Swan | Long-billed Curlew | Oppossum |
| **COOTS** | Killdeer | Raccoon |
| American Coot | Black-crowned Night Heron | Striped Skunk |
| **OTHERS** | Greater Sandhill Crane | Gray Fox |
| Black-tailed Deer | Lesser Sandhill Crane | Beaver |
| | White-Faced Ibis | Muskrat |
| | | Coyote |
| | | Mink |

A complete listing of species may be found in USFWS, 1987.

## POTENTIAL IMPACTS

The USFWS has inventoried the presence of potentially harmful contaminants on national wildlife refuges throughout the United States, and has concluded that circumstantial evidence indicates a priority need for reconnaissance monitoring of agricultural drainwater flowing into the Sacramento National Wildlife Refuge (U.S. Fish and Wildlife Service, 1986). There is no direct evidence that contaminants are moving into the refuge, but rice irrigation return flows, avian botulism, and high concentrations of selenium were identified as potential nonpoint source related problems. Sacramento NWR refuge personnel suspect Logan Creek as a source of potential water quality related problems within the refuge. The stream carries agricultural return flows and the refuge is downstream from the Willows sewage treatment plant and a fertilizer applicator facility.

Potential nonpoint source agricultural impacts on water quality of refuge inflows may include fertilizer residues, sediment loads, elevated trace element and mineral levels, rice herbicide and other pesticide concentrations. Salts, sediment, and pesticides discharged from rice fields have resulted in measurable changes in Sacramento River water quality (Tanji et al., 1982 and Finlayson, 1983). Rice irrigation return flows may also significantly affect resident aquatic organisms and the water quality of Logan Creek. The use of herbicides to control aquatic weeds is a major factor contributing to high yields of rice in the Sacramento Valley. Water quality monitoring in previous seasons has documented the presence of molinate (Ordram ®) and thiobencarb (Bolero ®) in Sacramento Valley irrigation drainage channels and the Sacramento River (Cornacchia, et al., 1984). The discharge of rice herbicides from agricultural drains generally begins in late April, peaks in late May to early June, and subsides by early July. Molinate, thiobencarb, and methyl parathion are the major pesticides used by the rice growers that may impact aquatic life. CDFG has attributed large fish kills in agricultural drains to the herbicide molinate (Finlayson and Lew, 1983). Thiobencarb is more acutely toxic to aquatic organisms than molinate, particularly to invertebrates. Ethyl and methyl parathion are organophosphorous pesticides that are used for the control of tadpole shrimp in rice fields. Research conducted within the Sacramento National Wildlife Refuge complex has shown that aerial applications of these compounds to rice fields are not acutely hazardous to wildlife, but there is evidence that methyl parathion may cause nervous disorders and significant inhibition of brain choloinesterase activity in some birds and mammals (Custer, el al., 1985).

Avian botulism outbreaks occur in late June through early October when Logan Creek flows are used to flood up waterfowl ponds. Refuge personnel are concerned that declining water quality may be related to the botulism problem (O'Halloran, 1986, personal communication). Avian botulism has been a chronic problem in California, with mortality rates as high as 40,000 waterfowl per year (Titche, 1988). The disease is caused by ingestion of toxin produced by a bacterium (Clostridium botulinum) in animal tissue. The soil may also provide habitat for this anerobic bacteria, and fluctuating water levels have also been associated with botulism problems. Transmission of the disease is enhanced by dense populations of waterfowl and poor habitat quality. Botulism outbreaks tend to occur in areas that have the presence of bacteria, and have been recently flooded. Warm temperatures and nutrient rich water are also associated with this problem, and therefore agricultural runoff supply water has been identified as a potential problem associated with this disease.

The California Department of Water Resources has reported high concentrations of selenium (10 to 390 µg/L range) in Stony Creek, Black Butte Reservoir, the Colusa Basin Drain, and the Sacramento River (Brown, 1985). Stony Creek drains Black Butte Reservoir, is diverted into the Glenn Colusa Canal as needed during the summer months, and is therefore a water source for the Sacramento NWR. Deformities and deaths of waterfowl in Kesterson Reservoir have been associated with selenium toxicosis. The U.S. Environmental Protection Agency (EPA) criterion for the protection of freshwater aquatic life is 5 µg/L acid soluble selenium. The USFWS policy is to only apply water to refuge lands which falls below 2 µg/L selenium.

There has been no previous attempt to characterize the water quality of the direct inflows to Sacramento NWR. There has been no direct evidence of a water quality impact on the aquatic ecosystem at this refuge, but adjacent intensive agricultural land use practices, the reliance of agricultural return flows as a supplemental water supply, and historic water quality monitoring data in the

Colusa Basin highlighted a need for this reconnaissance level assessment of potential nonpoint source water quality impacts.

## WATER QUALITY MONITORING

Agricultural drainage has been identified as a potential threat to wildlife populations in the Sacramento NWR. Potential impacts from trace element, nutrient, and pesticide concentrations in refuge water supply warranted a reconnaissance level water quality monitoring program which was initiated in August 1986 to assess the quality of the Sacramento NWR water inflows for the current beneficial use. Surface water, including agricultural drainage, was evaluated for general minerals, trace elements, nutrients, and pesticide concentrations. Sediment was collected from four drain locations and evaluated for trace element composition.

Water quality guidelines and criteria for the protection of freshwater aquatic life are shown in Table 2.

**Table 2. EPA Ambient Water Quality Criteria for the Protection of Freshwater Aquatic Life**

| Constituent | Recommended Criteria 4 day average | 1 hour average - µg/l - * | Maximum |
|---|---|---|---|
| pH | | | 9.0 pH units |
| Alkalinity | | | > 20,000 |
| Arsenic | 190 | 360 | |
| Cadmium | 0.55 | 1.4† | |
| Chromium (III) | 98† | 820 | |
| Chromium (VI) | 11† | 16 | |
| Copper | 5.4† | 7.5 | |
| Iron | | | 1,000 |
| Lead (inorganic) | 0.99† | 25 | |
| Mercury | 0.012 | 2.4 | |
| Nickel | 73 | 653 | |
| Selenium | 5 | 20 | |
| Silver | | | 13 |
| Zinc | 49† | 54 | |

* Acid soluble metals, value not to be exceeded more than once every 3 years on the average
† Value increases with hardness increase > 40 mg/L
(Reference: Marshack, 1989)

Water quality monitoring results from surface water inflows to the refuge have been evaluated with regard to these criteria. It should be recognized that the EPA criteria have been specifically developed for the protection of fish, shellfish, and other invertebrates. Although these criteria may not be directly applicable to the protection of wildlife habitat utilized by a wide variety of wildlife species, they are the best guidelines available at the present time for the prevention of negative impacts on the wildlife resource.

## Surface Water Quality

Surface water quality monitoring sites are shown in Figure 4. The water quality monitoring site indexes are described in Table 3. Surface water inflows carrying agricultural drainage to the refuge were sampled monthly August and September 1986, and March through September 1987. Background water quality samples were collected from the upper reach of Logan Creek above the irrigated lands of the GCID. The GCC 26.2 Lateral freshwater deliveries to the refuge were sampled three times throughout the course of this study. All monthly grab samples were analyzed for general minerals and total recoverable trace elements. Water temperature, pH, and electical conductivity were measured in the field. Mineral samples were collected in linear polyethylene bottles and kept on ice until delivery to the laboratory for analysis. Selenium and other trace element samples were collected in acid-rinsed polyethylene bottles, and preserved with ultra-pure nitric acid to lower the pH of the sample to less than 2 pH units. A quality assurance and control program included the evaluation of spike and duplicate samples in the laboratory. In addition, blind replicate samples were collected at ten percent of the field sites, and fifty percent of the blind replicates were spiked with known concentrations as an additional check on laboratory performance. All reported results fall within the quality assurance tolerance guidelines.

### Mineral Concentrations

Mineral water quality of all surface water inflow is reported in Table 3. Salinity measured as electrical conductivity (EC) ranged from 200 - 340 µmhos/cm in the GCID canals, 220 - 700 µmhos/cm in the Willows STP outfall, 250 - 635

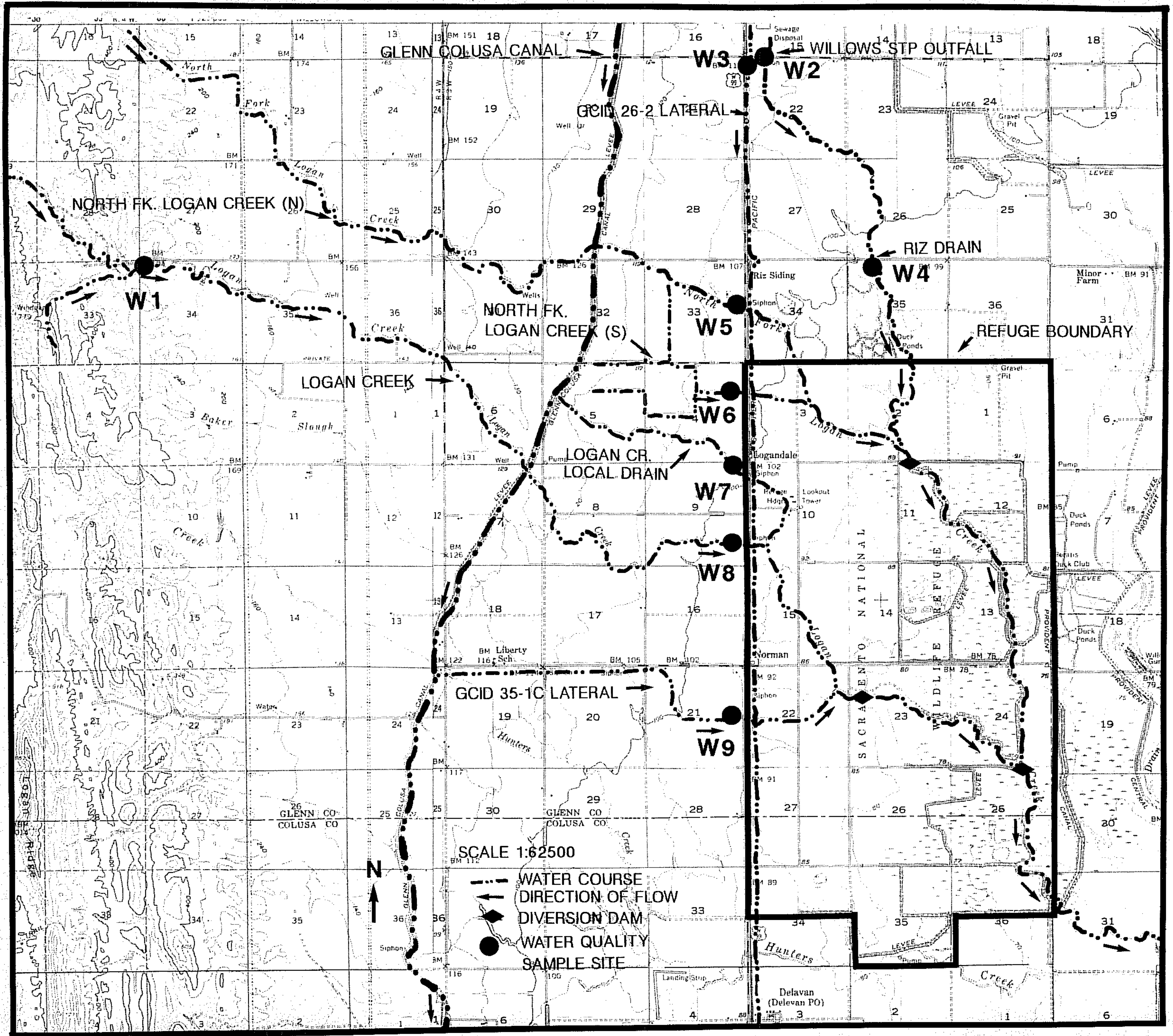



Fig. 4. Water Quality Monitoring Stations

**Table 3. Mineral Water Quality of Refuge Water Supply.**

| SAMPLE SITE | SAMPLE LOCATION | SAMPLE DATE | TEMP. °F | EC µmos/cm | pH | Ca | Mg | Na | K | Cl | SO4 | B | TDS | TOTAL ALK. | TOTAL HARD | SUS SOLIDS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | ----- | mg/l | ----- | | | | | |
| W1 | LOGAN CREEK | 9/2/86 | 72 | 850 | 8.1 | 18 | 33 | 98 | 2.4 | 40 | 39 | 0.43 | 500 | 340 | 220 | 8 |
| | END RD. 60 | 3/25/87 | 59 | 747 | 7.8 | | | | | 44 | | 0.24 | | | | |
| W2 | WILLOW STP | 6/25/87 | 85 | 580 | 9.1 | | | | | 28 | 38 | 0.45 | | 230 | | |
| | OUTFALL | 7/28/87 | 72 | 550 | 7.3 | | | | | 18 | 30 | 0.30 | | 200 | | |
| | | 8/20/87 | 68 | 220 | 7.2 | | | | | 16 | 22 | 0.19 | | 162 | | |
| | | 9/3/87 | 77 | 700 | 8.5 | | | | | 26 | 60 | 0.26 | | 230 | | |
| W3 | GCC 26.2 | 8/20/86 | | 340 | 7.8 | 16 | 14 | 26 | 2.1 | 6 | 24 | 0.13 | 190 | 140 | 110 | 45 |
| | LATERAL | 3/25/87 | 60 | 202 | 8.0 | | | | | 15 | | < 0.1 | | | | |
| | | 8/20/87 | 64 | 200 | 6.3 | | | | | 4 | 14 | 0.07 | | 84 | | |
| W4 | RIZ DRAIN | 8/20/86 | 69 | 320 | 7.5 | 15 | 14 | 26 | 1.4 | 6 | 26 | 0.14 | 210 | 130 | 100 | 29 |
| | RIZ ROAD | 9/2/86 | 72 | 380 | 7.6 | 21 | 14 | 33 | 1.6 | 7 | 28 | 0.19 | 230 | 150 | 110 | 54 |
| | | 5/26/87 | 65 | 485 | 8.2 | | | | | 8 | 64 | 0.20 | | | | |
| | | 6/25/87 | 78 | 380 | 7.7 | | | | | 8 | 34 | 0.31 | | 160 | | |
| | | 7/28/87 | 67 | 385 | 7.0 | | | | | 8 | 32 | 0.27 | | 155 | | |
| | | 8/20/87 | 66 | 300 | 7.4 | | | | | 7 | 35 | 0.14 | | 125 | | |
| | | 9/3/87 | 68 | 380 | 7.6 | | | | | 7 | 32 | 0.12 | | 125 | | |
| W5 | NORTH FORK | 8/20/86 | 71 | 310 | 8.1 | 14 | 14 | 28 | 1.0 | 7 | 17 | 0.13 | 180 | 125 | 100 | 38 |
| | LOGAN CR | 9/2/86 | 68 | 300 | 7.8 | 16 | 12 | 23 | 1.5 | 7 | 14 | 0.17 | 180 | 125 | 94 | 47 |
| | (NORTH) | 3/25/87 | 64 | 506 | 8.2 | | | | | 14 | | 0.16 | | | | |
| | | 5/26/87 | 64 | 345 | 8.0 | | | | | 7 | 31 | 0.14 | | | | |
| | | 6/25/87 | 80 | 360 | 7.8 | | | | | 9 | 22 | 0.34 | | 160 | | |
| | | 7/28/87 | 68 | 370 | 7.2 | | | | | 4 | 22 | 0.25 | | 160 | | |
| | | 8/20/87 | 67 | 420 | 7.6 | | | | | 15 | 31 | 0.18 | | 184 | | |
| | | 9/3/87 | 68 | 500 | 7.8 | | | | | 11 | 30 | 0.17 | | 170 | | |
| W6 | NORTH FORK | 8/20/86 | 70 | 270 | 7.8 | 12 | 10 | 20 | 1.0 | 5 | 16 | 0.12 | 180 | 110 | 86 | 32 |
| | LOGAN CR | 9/2/86 | 71 | 410 | 8.2 | 24 | 15 | 40 | 1.0 | 8 | 31 | 0.25 | 230 | 180 | 120 | 56 |
| | (SOUTH) | 5/26/87 | 63 | 287 | 8.5 | | | | | 5 | 27 | 0.18 | | | | |
| | | 7/28/87 | 66 | 300 | 7.5 | | | | | < 1 | 17 | 0.17 | | 130 | | |
| | | 8/20/87 | 68 | 250 | 7.6 | | | | | 5 | < 2 | 0.14 | | 120 | | |
| | | 9/3/87 | 68 | 350 | 7.7 | | | | | 6 | 13 | 0.14 | | 140 | | |
| W7 | AREA DRAIN | 8/20/86 | 70 | 330 | 8.5 | 15 | 13 | 28 | 1.9 | 5 | 20 | 0.17 | 190 | 148 | 100 | 48 |
| | SOUTH OF | 9/2/86 | 70 | 470 | 8.0 | 25 | 16 | 43 | 0.6 | 6 | 27 | 0.24 | 250 | 190 | 140 | 29 |
| | LOGANDALE | 7/28/87 | 70 | 450 | 7.6 | | | | | 5 | 26 | 0.29 | | 200 | | |
| | | 8/20/87 | 67 | 450 | 7.6 | | | | | 10 | 28 | 0.25 | | 218 | | |
| | | 9/3/87 | 68 | 450 | 7.8 | | | | | 8 | 32 | 0.24 | | 218 | | |
| W8 | LOGAN CREEK | 8/20/86 | 71 | 250 | 8.6 | 14 | 10 | 18 | 1.3 | 4 | 14 | 0.12 | 180 | 106 | 80 | 34 |
| | RD 99 | 9/2/86 | 70 | 290 | 8.1 | 14 | 12 | 22 | 1.2 | 6 | 16 | 0.17 | 160 | 130 | 96 | 33 |
| | | 3/25/87 | 62 | 635 | 8.0 | | | | | 6 | | 0.22 | | | | |
| | | 5/26/87 | 64 | 400 | 6.4 | | | | | 5 | 28 | 0.11 | | | | |
| | | 6/25/87 | 86 | 275 | 7.9 | | | | | 5 | 19 | 0.20 | | 115 | | |
| | | 7/28/87 | 66 | 320 | 7.9 | | | | | < 1 | 19 | 0.11 | | 140 | | |
| | | 8/20/87 | 66 | 290 | 7.4 | | | | | 5 | 17 | 0.13 | | 132 | | |
| | | 9/3/87 | 64 | 380 | 7.5 | | | | | 7 | 20 | 0.13 | | 142 | | |
| W9 | GCID 35-1C | 8/20/86 | 71 | 200 | 7.6 | 9 | 6 | 12 | 1.3 | 3 | 10 | 0.06 | 130 | 72 | 60 | 40 |
| | LATERAL | 9/2/86 | 70 | 230 | 7.8 | 15 | 7 | 17 | 1.2 | 4 | 12 | 0.13 | 120 | 88 | 68 | 31 |
| | | 8/20/87 | 64 | 200 | | | | | | | | | | | | |

μmhos/cm in the surface drains flowing into the refuge, and 747 - 800 μmhos/cm at the Logan Creek background site above irrigated agriculture. The median electrical conductivity for freshwater supplies was 200 μmhos/cm and 350 μmhos/cm for other surface water drains carrying agricultural return flows. These low salinity levels illustrate the effect of dilution of natural Logan Creek water with freshwater used for irrigation from the GCID.

A Piper trilinear plot (Fig. 5) illustrates the ionic chemical composition of surface water utilized by the refuge. The relative contributions of major cations and anions to the total ionic composition of each water sample for which an extensive mineral analysis was performed is plotted on this diagram. The background sample collected from the upper Logan Creek watershed is a magnesium bicarbonate type water typical of foothill streams and ground water associated with the magnesium silicate rich Franciscan Formation on the west side of the Sacramento Valley (Davis, 1961 and Jennings and Strand, 1960). All other water samples show a bicarbonate dominant anion, but mixed calcium-magnesium-sodium cation character reflecting the blending of upper Sacramento River Basin water, local westside watershed contributions, and agricultural return flows.

Trace Element Concentrations

Trace element analyses of surface water samples are shown in Table 4. Arsenic was detected in the March 1987 sample from Logan Creek at the refuge boundary at 41 μg/L. This is below the EPA criterion for the protection of aquatic life (Table 2). Cadmium and molybdenum were not measured above the limits of analytical detection. Descriptive statistics of the routinely detected trace elements are profiled in Table 5. Statistical variation of these trace element concentrations are depicted in boxplots (Fig. 6).

Copper was routinely detected in every water sample. The Logan Creek background level for copper was measured at 1 μg/L. The GCID 26.2 and 35-1C laterals ranged from 4 - 6 μg/L total recoverable copper, while the Willows STP outfall to Logan Creek ranged from 5 - 6 μg/L. The remaining surface water inflows carrying agricultural return flows contained copper from 2 - 22 μg/L,

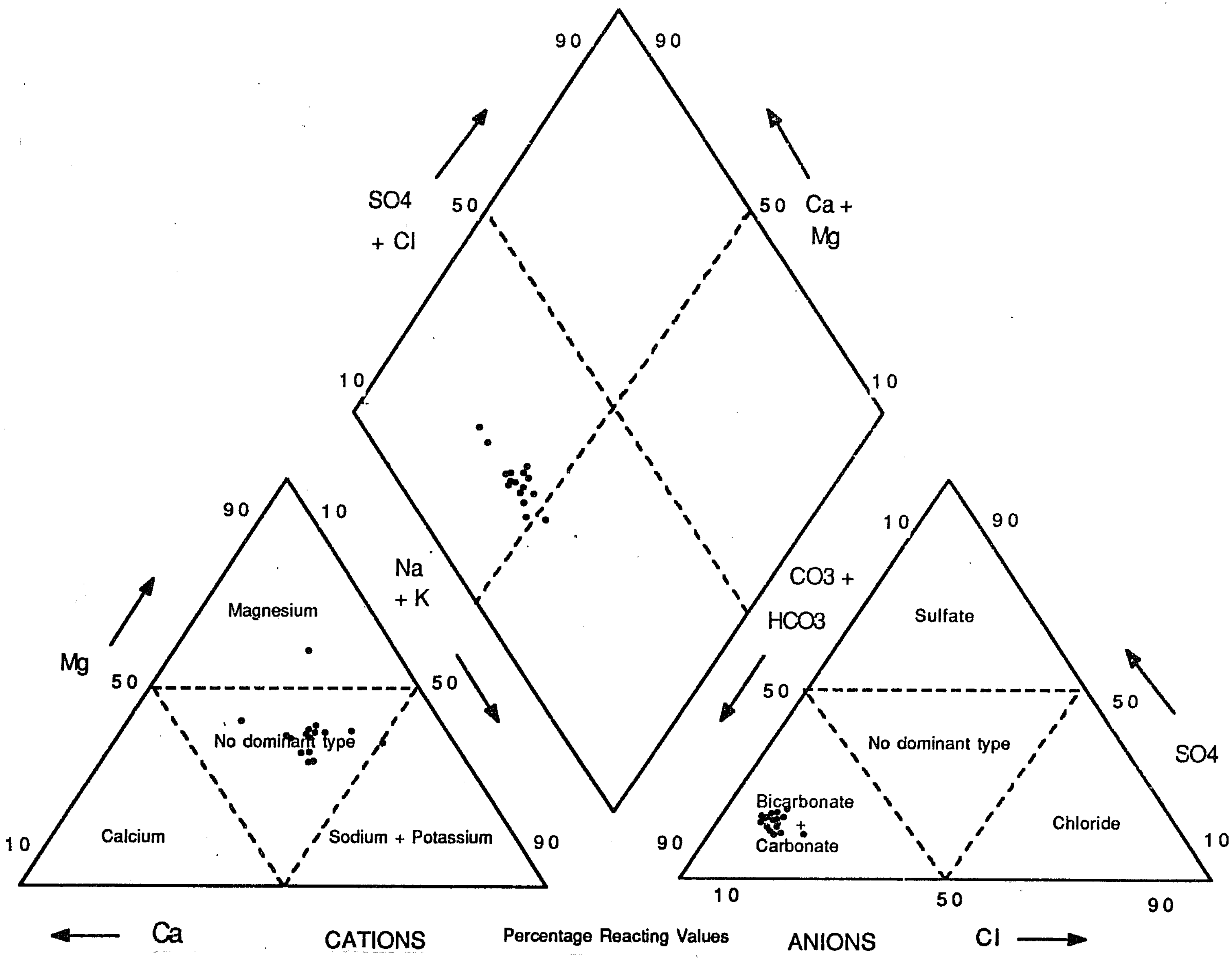


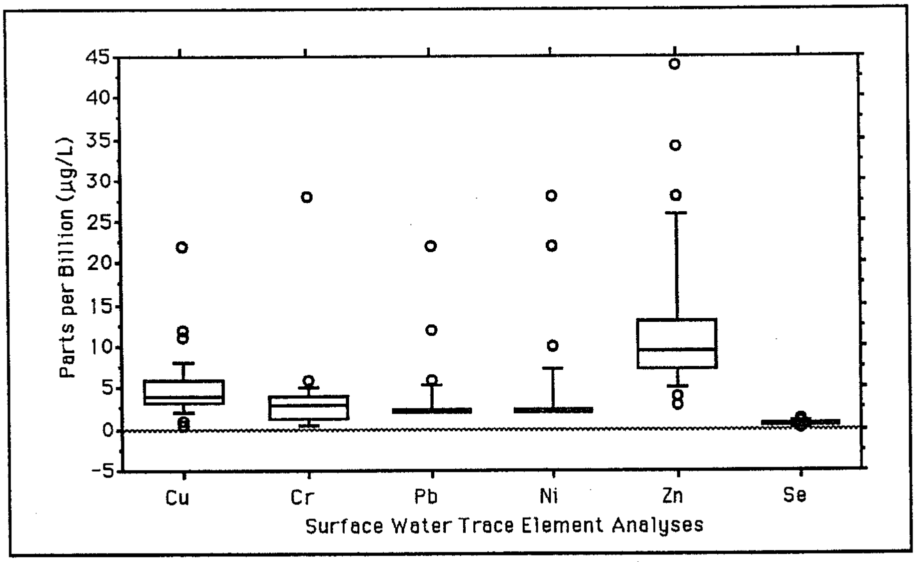

Figure 5. Chemical Composition of Refuge Water Supply

**Table 4. Trace Element Concentrations in Refuge Water Supply.**

| SAMPLE SITE | SAMPLE LOCATION | SAMPLE DATE | EC µmhos/cm | As | Cd | Cu | Cr | Pb | Ni | Zn | Se | Mo |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | --- µg/L total recoverable trace elements --- | | | | | | | | |
| W1 | Logan Creek W. end Rd. 60 | 9/2/86 | 850 | < 10 | < 1 | 1 | 1 | < 5 | < 5 | 4 | 0.4 | < 5 |
| | | 3/25/87 | 747 | < 4 | < 0.1 | < 1 | < 1 | < 5 | < 5 | 34 | 0.6 | < 5 |
| W2 | Willows STP Oufall | 6/25/87 | 460 | | | 6 | 4 | < 5 | < 5 | 13 | 1.1 | |
| | | 7/28/87 | 600 | | | 5 | 1 | < 5 | < 5 | 10 | 0.5 | |
| | | 8/20/87 | 220 | | | | | | | | 0.7 | |
| | | 9/3/87 | 700 | | | | | | | | 0.6 | |
| W3 | GCC 26.2 Lateral | 8/20/86 | 120 | < 10 | < 1 | 6 | 1 | < 5 | < 5 | 22 | 0.4 | < 5 |
| | | 3/25/87 | 290 | < 4 | < 0.1 | 4 | 4 | < 5 | < 5 | 25 | 0.3 | < 5 |
| | | 8/20/87 | 200 | | | | | | | | 0.2 | |
| W4 | Riz Drain Riz Road | 8/20/86 | 320 | < 10 | < 1 | 3 | < 1 | < 5 | < 5 | 9 | 0.4 | < 5 |
| | | 9/2/86 | 320 | < 10 | < 1 | 4 | 5 | < 5 | < 5 | 13 | 0.6 | < 5 |
| | | 5/26/87 | 500 | < 4 | < 1 | 12 | 5 | < 5 | < 5 | 7 | 0.3 | < 5 |
| | | 6/25/87 | 300 | | | 11 | 4 | < 5 | < 5 | 7 | 1.0 | |
| | | 7/28/87 | 380 | | | 6 | 5 | < 5 | 10 | 8 | 0.6 | |
| | | 8/20/87 | 300 | | | | | | | | 0.3 | |
| | | 9/3/87 | 380 | | | | | | | | 0.7 | |
| W5 | North Fork Logan Creek (North) | 8/20/86 | 320 | < 10 | < 1 | 4 | < 1 | < 5 | < 5 | 11 | 0.5 | < 5 |
| | | 9/2/86 | 263 | < 10 | < 1 | 3 | 4 | < 5 | < 5 | 12 | 0.6 | < 5 |
| | | 3/25/87 | 506 | < 4 | < 0.1 | 2 | 4 | < 5 | < 5 | 28 | 0.4 | < 5 |
| | | 5/26/87 | 265 | < 4 | < 1 | 6 | 3 | < 5 | < 5 | 6 | 0.6 | < 5 |
| | | 6/25/87 | 320 | | | 6 | 6 | < 5 | 6 | 8 | 0.4 | |
| | | 7/28/87 | 380 | | | 4 | 3 | < 5 | 5 | 6 | 0.3 | |
| | | 8/20/87 | 420 | | | | | | | | 0.5 | |
| | | 9/3/87 | 500 | | | | | | | | 0.4 | |
| W6 | North Fork Logan Creek (South) | 8/20/86 | 350 | < 10 | < 1 | 4 | < 1 | < 5 | < 5 | 11 | 0.4 | < 5 |
| | | 9/2/86 | 385 | < 10 | < 1 | 4 | 5 | < 5 | < 5 | 15 | 0.9 | < 5 |
| | | 5/26/87 | 245 | < 4 | < 1 | 6 | 3 | < 5 | < 5 | 5 | 0.6 | < 5 |
| | | 7/28/87 | 300 | | | 3 | 2 | < 5 | < 5 | 3 | 0.2 | |
| | | 8/20/87 | 250 | | | | | | | | 0.4 | |
| | | 9/3/87 | 350 | | | | | | | | 0.4 | |
| W7 | Area Drain South of Logandale | 8/20/86 | 340 | < 10 | < 1 | 4 | < 1 | < 5 | < 5 | 16 | 0.4 | < 5 |
| | | 9/2/86 | 395 | < 10 | < 1 | 2 | 3 | < 5 | < 5 | 8 | 0.4 | < 5 |
| | | 7/28/87 | 460 | | | 6 | 3 | < 5 | < 5 | 5 | 0.5 | |
| | | 8/20/87 | 450 | | | | | | | | 0.7 | |
| | | 9/3/87 | 450 | | | | | | | | 0.5 | |
| W8 | Logan Creek at Rd. 99 | 8/20/86 | 255 | < 10 | < 1 | 4 | < 1 | < 5 | < 5 | 10 | 0.3 | < 5 |
| | | 9/2/86 | 260 | < 10 | < 1 | 3 | 3 | < 5 | < 5 | 9 | 0.6 | < 5 |
| | | 3/25/87 | 620 | 41 | < 0.1 | 22 | 28 | 6 | 28 | 44 | 1.2 | < 5 |
| | | 5/26/87 | 400 | < 4 | < 1 | 3 | 2 | 22 | < 5 | 7 | 0.1 | < 5 |
| | | 6/25/87 | 275 | | | 7 | 3 | 12 | < 5 | 6 | 1.0 | |
| | | 7/28/87 | 320 | | | 5 | 4 | 5 | 5 | 8 | 0.3 | |
| | | 8/20/87 | 290 | | | | | | | | 0.4 | |
| | | 9/3/87 | 380 | | | | | | | | 0.4 | |
| W9 | GCID 35-1C Lateral | 8/20/86 | 200 | < 10 | < 1 | 4 | < 1 | < 5 | < 5 | 13 | 0.4 | < 5 |
| | | 9/2/86 | 230 | < 10 | < 1 | 4 | 3 | < 5 | < 5 | 12 | 0.4 | < 5 |

Table 5. Descriptive statistics of trace element water quality data.

| Statistics | Copper | Chromium | Lead | Nickel | Zinc | Selenium |
|---|---|---|---|---|---|---|
| Mean | 5 | 4 | 3 | 4 | 12 | 0.5 |
| Std. Deviation | 3.8 | 4.77 | 3.9 | 5.8 | 9.11 | 0.235 |
| Std. Error | 0.69 | 0.84 | 0.69 | 1.02 | 1.61 | 0.035 |
| Variance | 15.1 | 22.8 | 15.6 | 33.7 | 83 | 0.055 |
| Coef. Variation | 75.6 | 135.7 | 124.9 | 145.2 | 73.8 | 46.24 |
| Count | 32 | 32 | 32 | 32 | 32 | 45 |
| Minimum | 0.5 | 0.5 | 2 | 2 | 3 | 0.1 |
| Maximum | 22 | 28 | 22 | 28 | 44 | 1.2 |
| Range | 21.5 | 27.5 | 20 | 26 | 41 | 1.1 |
| Geometric Mean | 4 | 2 | 2 | 3 | 10 | 0.46 |




Explanation: Boxes represent the middle fifty percent of the data.
Lines extending from the boxes represent the range of data.
The outlying data points above and below the 10th and 90th percentile are represented as open circles.

Figure 6. Boxplots of Total Trace Element Concentrations for Water Inflow to Sacramento National Wildlife Refuge.

and the median copper concentration of all samples was 4 µg/L. The presence of copper above background level is expected, as copper compounds are used extensively as an algacide in the control blue-green filamentous algae in rice fields. The EPA recommended criterion for the protection of aquatic life is 5.4 µg/L acid soluble copper at a water hardness of ≤ 40 mg/L (Table 2). Table 6 shows the copper concentrations detected in the drains compared to the criterion for copper which has been corrected for hardness by the following equation:

Corrected copper criterion = e(0.8545)(ln (hardness mg/L)) - 1.465 µg/L.

Table 6. Copper concentrations compared to protective criteria which have been corrected for water hardness.

| SITE | LOCATION | DATE | Cu (µg/L) | HARDNESS | Cu Criterion (µg/L) |
|---|---|---|---|---|---|
| W1 | Logan Cr. bkgrnd | 9/2/86 | 1 | 220 | 11 |
| W3 | GCC 26.2 Lateral | 8/20/86 | 6 | 110 | 10 |
| W4 | Riz Rd. Drain | 8/20/86 | 3 | 100 | 9 |
| | | 9/2/86 | 4 | 110 | 10 |
| W5 | N.Fk.Logan Cr.(N) | 8/20/86 | 4 | 100 | 9 |
| | | 9/2/86 | 3 | 94 | 9 |
| W6 | N.Fk.Logan Cr.(S) | 8/20/86 | 4 | 86 | 9 |
| | | 9/2/86 | 4 | 120 | 10 |
| W7 | Drain S/Logandale | 8/20/86 | 4 | 100 | 9 |
| | | 9/2/86 | 2 | 140 | 10 |
| W8 | Logan Cr. Rd.99 | 8/20/86 | 4 | 80 | 9 |
| | | 9/2/86 | 3 | 96 | 9 |
| W9 | GCID 35-1C | 8/20/86 | 4 | 60 | 8 |
| | | 9/2/86 | 4 | 68 | 8 |

This criterion adjustment could only be evaluated for selected water samples for which a total hardness analysis was completed. The results of this comparison indicate that water samples for which hardness was evaluated were below the corrected criterion, although two samples from the drain at Riz Road approach and may have exceeded the criterion at 11 to 12 µg/L copper. A one time sample taken 25 March 1987 from Logan Creek at the refuge boundary (W8) showed elevated levels of copper at 22 µg/L.

Total recoverable chromium concentrations ranged from < 1 to 28 µg/L, and the median concentration for all samples was 3 µg/L. There is no guideline for impacts on wildlife from total recoverable chromium at the present time. The recommended criterion for trivalent chromium is 98 µg/L, and the criterion for the more toxic hexavalent chromium is 11 µg/L. The data collected in this survey suggest that chromium levels in this refuge supply water are not likely to negatively impact the wildlife resources.

Lead was not detected above the < 5 µg/L limit of analytical detection at eight of the nine monitoring sites. Logan Creek at Road 99 at the western refuge boundary was the only site with detectable lead concentrations which ranged from 5 - 22 µg/L in four samples. These detections are all above the 0.99 µg/L level recommended for the protection of freshwater aquatic life. The source of this elevated lead in unkown, but agricultural drainage is an unlikely source in these four samples taken March - July of 1987.

Nickel was detected five times at three sites at a range of 5 - 28 µg/L. Zinc was routinely detected in every water sample, and concentrations ranged from 3 - 44 µg/L with a median of 10 µg/L. All zinc and nickel detections were below the present criterion for the protection of freshwater aquatic life.

Selenium has been a trace element of concern at wildlife refuges throughout the western United States since it has been linked with embryonic deformities in waterfowl and shorebirds. The USFWS identified elevated selenium from agricultural drainage to be a potential nonpoint source contaminant at Sacramento NWR (USFWS, 1986).

Selenium was measured on a monthly basis at all sites in the study area. Selenium levels for all samples ranged from 0.1 µg/L - 1.2 µg/L, with a median of 0.4 µg/L. The background level of selenium in Logan Creek above all irrigated agriculture averaged 0.5 µg/L. The present EPA selenium criterion for the protection of aquatic life is 5 µg/L, and the USFWS uses 2 µg/L as a protection level for water applied to wildlife habitat. All 45 samples analyzed in this survey were below these levels of concern.

The results of this monitoring do not support earlier findings of elevated selenium in the Sacramento Valley as reported by Brown (1985). Historical data on selenium concentrations evaluated before 1984 are of questionable value, as inappropriate colorimetric methods were used for the analyses. Since that time, hydride generation and atomic absorption techniques have been used to accurately quantify selenium levels. The low levels of selenium measured in this study are in agreement with results of a 1984 - 1988 Regional Board stream water quality survey for selenium in the Sacramento River and its tributaries where only eleven of 366 water samples showed selenium concentrations exceeding 1 µg/L, and the maximum level detected was 1.6 µg/L (Chilcott and Westcot, 1988). Furthermore, CDFG used Sacramento NWR as a background site in a selenium verification study to represent an area where human activities have not altered selenium levels in the environment, and therefore animal tissue concentrations of selenium represented exposure to background levels (White, et. al, 1987).

## Nutrient Concentrations

Nutrient levels in refuge supply water were measured twice at three selected sites. The Willows Sewage Treatment Plant outfall ditch was monitored as it is tributary to Logan Creek, and refuge personal have expressed concern with the quality of treatment plant discharges to refuge wetlands (O'Halloran, 1986, personal communication). A fertilizer formulation facility was identified as a potential discharge to Logan Creek upstream of the treatment plant outfall. This facility was observed throughout the course of the study with no evidence of discharge. North Fork Logan Creek (North) and Logan Creek were also monitored at the refuge boundary to represent potential agricultural drainage loading of nutrients to refuge wetlands. Nutrient samples were collected in one gallon plastic containers, placed on ice, and delivered to the laboratory for analysis within six hours of collection. Nutrient analyses included nitrate, total potassium, ammonia as nitrogen, total kjeldahl nitrogen as nitrogen, total phosphate as phosphorous, and orthophosphate as phosphorous. Results of this assessment are reported in Table 7.

Table 7. Nutrient Concentrations in Refuge Water Supply.

| SAMPLE SITE | SAMPLE DATE | - mg/L - | | | | | |
|---|---|---|---|---|---|---|---|
| | | Nitrate as NO3 | Total Potassium | Ammonia as N | Total Kjeldahl Nitrogen as N | Total Phosphate as P | OrthoPhoshate as P |
| W2 | 6/25/87 | <1 | 5 | 0.6 | 2 | 1 | 0.9 |
| | 7/28/87 | < 1 | 3 | 7 | 0.6 | 2 | 5 |
| W5 | 6/25/87 | 2 | 1 | < 0.02 | 0.4 | 0.1 | 0.1 |
| | 7/28/87 | <1 | < 0.02 | 0.4 | 0.1 | 0.1 | 0.8 |
| W8 | 6/25/87 | 2 | 1 | < 0.02 | 0.3 | 0.1 | 0.1 |
| | 7/28/87 | <1 | 0.04 | < 0.02 | 0 | 0.1 | 0.6 |

SITE LOCATION: W2 Willows STP Outfall
W5 North Fork Logan Creek
W8 Logan Creek

Water quality guidelines for nutrient impacts on wetlands have not been established. However, the EPA has established freshwater aquatic life criteria for ammonia which vary with pH, water temperature, and whether salmonoids or other coldwater species are present or absent (EPA, 1984). Freshwater aquatic life criteria do not apply to waterfowl, but these species are an important component of the wildlife ecosystem at the refuge, and are a food source for species higher in the food chain. Ammonia levels measured in refuge inflow are compared to these protective guidelines in Table 8.

Table 8. Ammonia Concentrations in Refuge Inflow Compared to Protective Criteria which varies with pH and water temperature.

| SAMPLE SITE | SAMPLE DATE | WATER TEMP ° C | pH | NH3 as N (mg/L) | Protective Criteria (mg/L) Salmonoids NH3 as N | No Salmonoids NH3 as N |
|---|---|---|---|---|---|---|
| W2 | 6/25/87 | 29 | 9.1 | 0.6 | 0.07 | 0.09 |
| | 7/28/87 | 22 | 7.3 | 7 | 1.23 | 1.73 |
| W5 | 6/25/87 | 27 | 7.8 | < 0.02 | 0.81 | 1.14 |
| | 7/28/87 | 20 | 7.2 | 0.4 | 1.23 | 1.73 |
| W8 | 6/25/87 | 30 | 7.9 | < 0.02 | 0.39 | 0.55 |
| | 7/28/87 | 19 | 7.9 | < 0.02 | 0.77 | 1.08 |

The limited data collected in this reconnaissance level survey suggests a point source loading of elevated ammonia to the Logan Creek watershed from the Willows Sewage Treatment Plant outfall ditch (Site W2). Ammonia levels in agricultural return flows from Logan Creek (Site W8) and North Fork of Logan Creek (N) (Site W5) were well below the protective criteria for the samples. In fact, three of the four agricultural drain samples were below the limit of analytical detection.

## Pesticides

The potential for agricultural chemical discharges into Sacramento National Wildlife Refuge through return flows from surrounding rice fields prompted the need for a monitoring program to quantify the levels of these chemicals and to determine if they may pose a threat to the wildlife resource. A weekly pesticide monitoring program was conducted14 May 1987 through 3 June 1987. This time period brackets the expected peak agricultural chemical runoff from rice fields in the Sacramento Valley. The primary pesticide use upstream of the refuge is rice herbicides, but additional pesticide analyses were evaluated due to the mixed cropping pattern upstream of the refuge (Figure 2). Samples were taken from four selected drains carrying the highest volume of agricultural return flows: Riz Drain (W4), North Fork Logan Creek (North) (W5), North Fork Logan Creek (South) (W6) and Logan Creek (W7). These drains were only sampled when significant flow was entering the refuge. The agricultural drains were sampled for thiocarbamates and organophosphorous pesticides on a weekly basis. Carbamates were evaluated on 14 May 1987 to correspond with the early use of carbofuran in the rice fields. An aromatic volatile organic screen was evaluated on a spot check basis to check for the presence of the pesticide carrier xylene. The Willows Sewage Treatment Plant outfall ditch was also sampled for aromatic volatile organics that may also be present in municipal and industrial discharges.

Pesticide samples were collected in one liter amber glass bottles which were sealed with teflon lined caps. Samples were collected 0.5 meters (20 inches) below the water surface at the midstream point of each drain. Water bottles were completely filled to exclude air and then immediately placed on ice. Results of this monitoring program are recorded in Table 9. Table 10 includes a complete list of the 33 organic chemicals evaluated in this survey along with the analytical detection limits used by the laboratory.

CDFG has established recommended guidelines for the protection of fish and aquatic organisms from rice herbicide exposure in agricultural drains (CDFG, 1986). The recommended interim guideline for molinate (Ordram ®) of 90 µg/L is based on the incipient lethal level to carp during a 21 day exposure. The recommended maximum guideline for thiobencarb (Bolero ®) is 24 µg/L based on the estimated safe level for larval striped bass in the Sacramento - San Joaquin Delta (Fagella and Finlayson, 1987). Guidelines have not been established for waterfowl or other wildlife species, but these current guidelines for aquatic life may serve as an indicator of potential problems. Bentazon (Basagran ®) is a third rice herbicide which was used extensively in the Colusa Basin during the course of this study. The EPA and CDFG consider bentazon to be nontoxic to fish and aquatic invertebrates (CDFG, 1986). Therefore, bentazon was not included in this monitoring program.

Table 9. Pesticide Concentrations Refuge Water Supply.

| SAMPLE SITE | SAMPLE DATE | EC µmhos/cm | Water Temp°F | PESTICIDE (µg/L) Thiocarbamates Molinate | Thiobencarb | Eptam | Carbamates Carbofuran | Carbaryl | OP Screen* | 602* Screen | Chlorinated Herbicides* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| W2 Willows STP | 14-May-87 | 700 | 68 | - | - | - | - | - | - | ND | - |
| | 26-May-87 | 800 | 66 | - | - | - | - | - | - | ND | - |
| | 3-Jun-87 | 460 | 74 | - | - | - | - | - | - | ND | - |
| W4 Riz Drain | 14-May-87 | 280 | 65 | 22 | ND | - | ND | ND | - | ND | - |
| | 20-May-87 | 390 | 66 | 32 | 0.6 | ND | - | - | ND | - | - |
| | 26-May-87 | 500 | 65 | 74 | ND | ND | - | - | ND | - | - |
| | 3-Jun-87 | 500 | 75 | 6 | ND | 0.8 | - | - | ND | - | - |
| W5 N. Fk. Logan (North) | 14-May-87 | 350 | 67 | 29 | ND | - | ND | ND | - | ND | - |
| | 20-May-87 | 320 | 69 | 32 | ND | ND | - | - | ND | - | - |
| | 26-May-87 | 265 | 64 | 10 | ND | ND | - | - | ND | - | - |
| | 3-Jun-87 | 370 | 74 | 5 | ND | ND | - | - | ND | - | - |
| W6 N. Fk. Logan (S) | 14-May-87 | 280 | - | 3 | ND | - | ND | ND | - | ND | - |
| | 20-May-87 | 275 | 69 | 46 | ND | ND | - | - | ND | - | - |
| | 26-May-87 | 245 | 63 | 92 | ND | ND | - | - | ND | - | - |
| W8 Logan Creek | 14-May-87 | 280 | 67 | 43 | ND | - | ND | ND | - | ND | - |
| | 20-May-87 | 280 | 67 | 4 | ND | ND | - | - | ND | - | - |
| | 26-May-87 | 400 | 64 | 37 | 0.5 | 3.3 | - | - | ND | ND | - |
| | 3-Jun-87 | 560 | 73 | 4 | ND | ND | - | - | ND | - | ND |

* Refer to Table 10 for complete list of chemicals evaluated in these screens.
ND = None detected (Refer to Table 10 for analytical detection limits).

Table 10. Analytical detection limits for organic chemical analyses of Sacramento NWR water supply.

| Chemical Class | Pesticide Active Ingredient | Minimum Detection Limit | Chemical Class | Pesticide Active Ingredient | Minimum Detection Limit |
|---|---|---|---|---|---|
| Thiocarbamates | Molinate | 0.2 - 0.4 µg/L | Aromatic Volatile Organics (EPA 602) | Benzene | 0.5 µg/L |
| | Thiobencarb | 0.2 - 0.4 µg/L | | Toluene | 0.5 µg/L |
| | Eptam (EPTC) | 0.2 - 0.4 µg/L | | Chlorobenzene | 0.5 µg/L |
| Carbamates | Carbofuran | 1.0 µg/L | | Ethyl Benzene | 0.5 µg/L |
| | Carbaryl | 1.0 µg/L | | m-Xylene | 0.5 µg/L |
| Organophosphorous Pesticides (OP Screen) | Phosdrin | 1.0 µg/L | | o & p-Xylenes | 0.5 µg/L |
| | Phorate (Thimet) | 1.0 µg/L | | 1,3-Dichlorobenzene | 0.5 µg/L |
| | Diazinon | 1.0 µg/L | | 1,4-Dichlorobenzene | 0.5 µg/L |
| | Disulfoton (Disyston) | 1.0 µg/L | | 1,2-Dichlorobenzene | 0.5 µg/L |
| | Dimethoate | 1.0 µg/L | Chlorinated Phenoxy Herbicides | 2,4-D | 0.25 µg/L |
| | Baytex (Fenthion) | 1.0 µg/L | | Fenac | 0.05 µg/L |
| | Chlorpyrifos (Dursban) | 0.4 - 1.0 µg/L | | 2,4,5-TP (silvex) | 0.05 µg/L |
| | Methyl Parathion | 0.4 - 1.0 µg/L | | 2,4,5-T | 0.05 µg/L |
| | Malathion | 1.0 µg/L | | MCPA | 10 µg/L |
| | Ethyl Parathion | 0.4 - 1.0 µg/L | | | |
| | DEF | 1.0 µg/L | | | |
| | Ethion | 1.0 µg/L | | | |
| | Carbophenothion | 1.0 µg/L | | | |
| | Azinphos-methyl | 10.0 µg/L | | | |

Molinate was the most consistantly detected pesticide in the four drains flowing into the wildlife refuge, and positive detections were obtained from every sample. The range of molinate concentrations detected during the rice herbicide runoff season was 3 - 92 µg/L. Concentrations of molinate during the critical runoff time are shown in Figure 7.

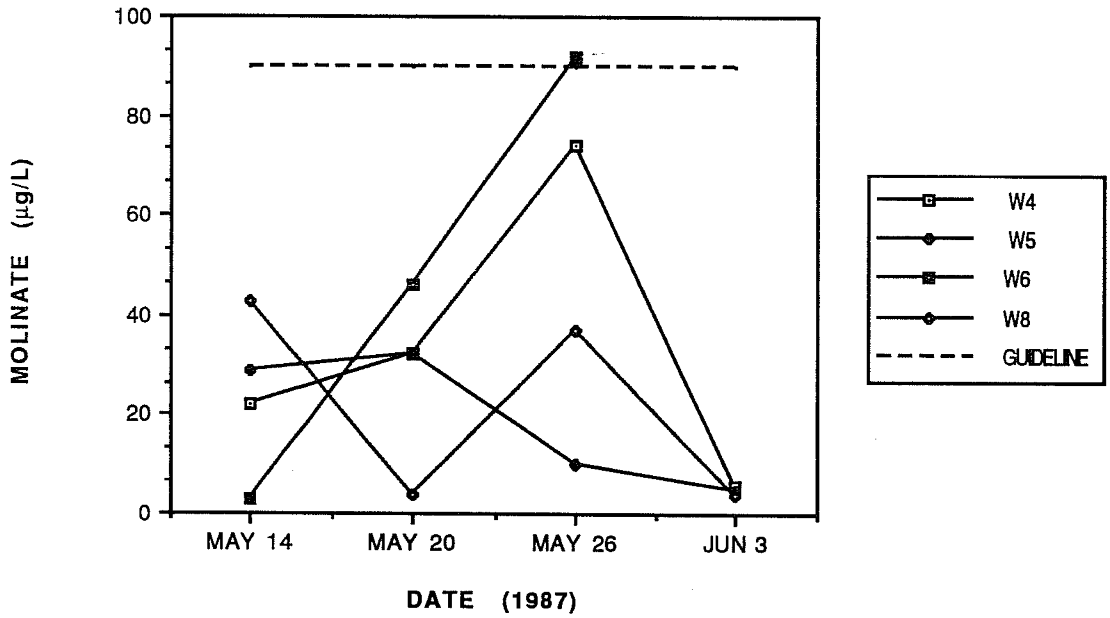



Figure 7. Molinate Concentrations in Refuge Water Supply.

All detections from Riz Drain (W4), North Fork Logan Creek (North) (W5), and Logan Creek (W8) were below the 90 µg/L recommended level established by CDFG. The peak sample from North Fork Logan Creek (South) (W6) was recorded at 92 µg/L on 26 May 1987. A confirmation sample was not taken at this monitoring station the following week (3 June 1987) as there was insignificant flow in the drain. The California Department of Food and Agriculture (CDFA) 1987 rice herbicide monitoring program revealed peak concentration of rice herbicides in the CBD and the Sacramento River between May 11 and June 4. The overall mass loading of rice herbicides was the lowest ever recorded due to increased grower participation in water recyling programs, longer holding times

times for field drainage discharges, and record high air temperatures in May which resulted in lower application rates due to phytoxicity and accelerated volatilization rates of both molinate and thiobencarb (CDFA, 1987). The detection of molinate over the recommended guideline during a season with low application rates signals the possibility of short term toxic exposure of wildlife to agrichemicals from rice drainage flowing into the wildlife refuge.

Thiobencarb was detected at extremely low levels in two of fifteen samples collected from the drains. The 0.5 µg/L in the Riz Drain and the 0.6 µg/L detection in Logan Creek are both well below the recommended guideline of 24 µg/L.

CDFG has also been concerned about the rice pesticides MCPA, methyl parathion, ethyl parathion, and carbofuran. These pesticides were not detected above the limits of analytical detection in any samples taken from refuge inflows. Results of samples evaluated for organophosphorous pesticides, carbamates, aromatic volatile organics, and chlorinated phenoxy herbicides were all below the limits of analytical detection.

EPTC (Eptam ®: s-ethyl dipropylthiocarbamate) was detected at 3.3 µg/L in Logan Creek on 26 May 1987 and at 0.8 µg/L in the Riz Drain on 3 June 1987. EPTC is a herbicide which is applied to alfalfa, sugarbeets, pasture and rangeland for weed control. These agricultural land uses were all present in the Logan Creek watershed during the time the pesticide samples were collected (Figure 2). A water quality guideline for wetlands habitat protection does not exist for EPTC.

## Sediment Chemical Analyses

Bottom sediment samples were collected from three drainage channels at the refuge boundary which convey agricultural return flows into Sacramento NWR, and one background site on Logan Creek above the irrigated agricultural lands (Fig. 8). The backgound site was included for an overview of concentrations present above irrigated lands, although the upstream background samples may not be directly comparable to downstream drain sites as trace element concentration in sediments generally increases with decrease in grain size,

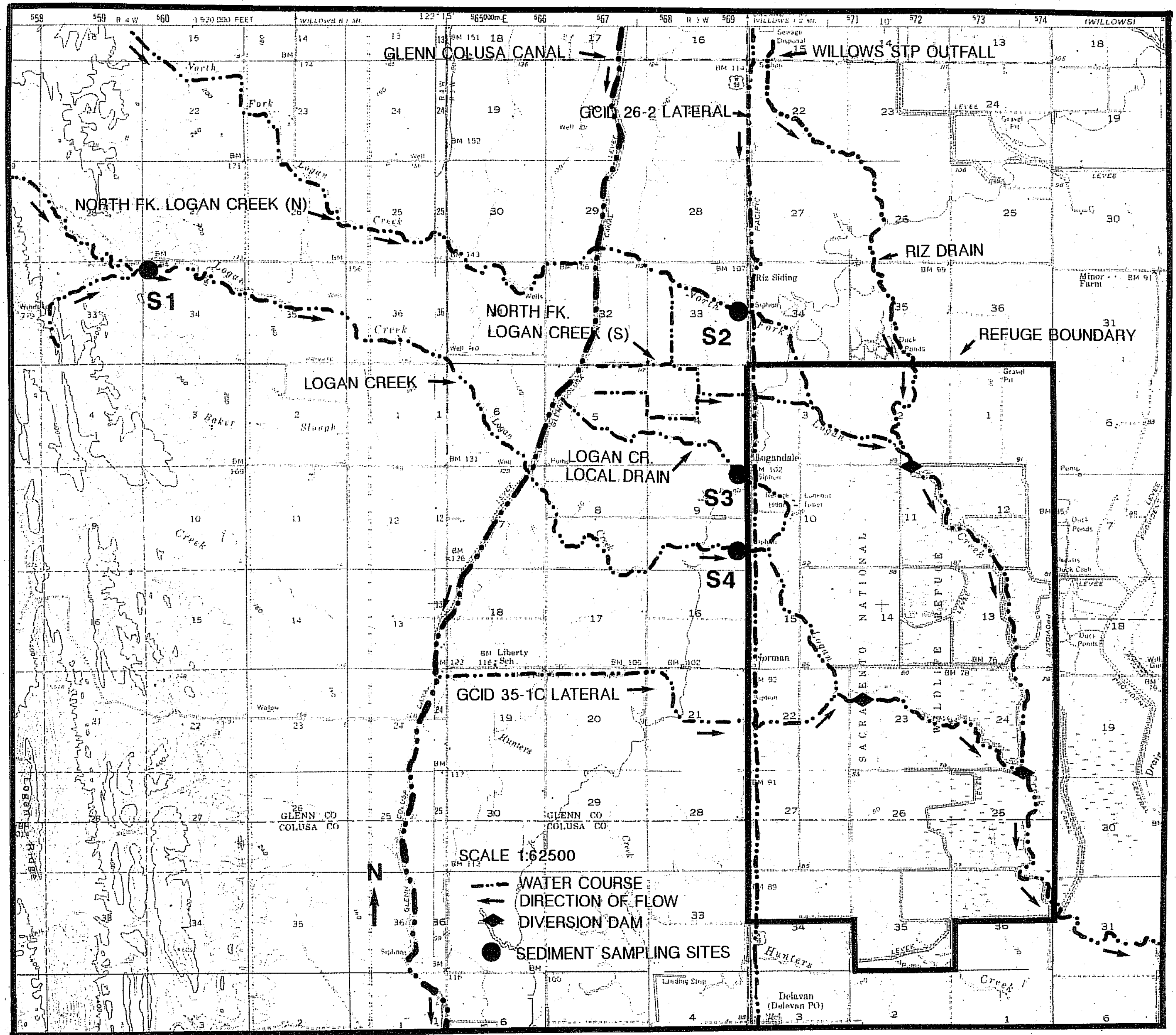



Fig. 8. Sediment Sample Sites

primarily because of the higher surface to volume ratio of finer particles. Analysis was based on total recoverable concentrations, and grain size fractions were not evaluated. Four samples were analyzed from drains which were carrying return flows at the time of collection, and one sample was analyzed from the background site. These samples each represent a composite of six collections from a random transect across each drain. A duplicate composite was submitted for analytical quality assurance. Each sample consisted of approximately 100 grams of wet sediment from the top 0 to 7 cm (0 to 3 inch) layer of bottom material. A modified soil sampler with an acid-rinsed PVC collection tube was utilized for the collection of material. Each composite sample was analyzed on a dry weight basis for 13 trace elements. All sediment data are reported in Table 11. Descriptive statistics of this data are summarized in Table 12, and the boxplots which follow depict the statistical variation of the sediment trace element concentrations (Fig. 9).

No specific protective guidelines have been established for the levels of trace elements in bottom sediments of natural systems. The relationship between bottom sediment chemistry and concentrations of trace elements in the overlying water is extremely variable and dependant on factors such as water pH, temperature, dissolved oxygen level, biological activity, and solubility characteristics of individual elements. Trace element availability for dissolution into the water column cannot be determined within the scope of this study. However, analysis of bottom sediment can indicate the presence of concentrations significantly greater than natural background levels. The analyses can also be compared to data collected at sites with documented problems related to wildlife contact with agricultural drainage.

Analytical results from the drain sediment samples are compared in Table 11 to geochemical baseline information from soils of the western United States as reported by the U.S. Geological Survey (Shacklette and Boerngen, 1984). The guidelines have been used to evaluate sediment quality data from the U.S. Department of the Interior's (DOI) agricultural drainage investigations at national wildlife refuges throughout the western United States. The expected 95 percentile geochemical baseline ranges were calculated from over 700 natural soil samples from locations west of the 97th meridian within the United States. Geometric means of the background data are also reported. The DOI Task Group

Table 11. Comparison of Sacramento NWR drain sediment chemistry to natural background levels and to sites with documented wildlife impairments.

| | Sacramento NWR Composite Sample Site | | | | Comparison Data | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S4 | Gray Lodge | Baseline Range | BGM | CA Mean | KR2 | TLDD-S |
| Constituent | Total dissolved, dry weight (mg/kg) | | | | | | | | | |
| Mercury | < 0.05 | 0.05 | < 0.05 | < 0.05 | 0.10 | 0.0085-0.25 | 0.046 | | | |
| Arsenic | 15.50 | 9.40 | 12.60 | 7.20 | 7.50 | 1.2 - 22 | 5.5 | | < 10 | 4.00 |
| Selenium | 0.4 | 0.25 | 0.65 | 0.7 | 0.55 | 0.039 - 1.4 | 0.23 | | **5.2** | 0.9 |
| Copper | 45 | 52 | 65 | 40 | 54 | 4.9 - 90 | 21 | 14.6 | 9 | 6 |
| Zinc | 69 | 77 | 127 | 60 | 74 | 17 - 180 | 55 | 60.4 | 39 | 20 |
| Nickel | 38 | 57 | 61 | 40 | 76 | 3.4 - 66 | 15 | 14.1 | 32 | 7 |
| Molybdenum | <1 | <1 | 1 | 1 | 2 | 0.18 - 4.0 | 0.85 | | < 2 | **18** |
| Cadmium | <1 | <1 | <1 | <1 | < 1 | | | 0.34 | < 2 | < 2 |
| Chromium | 49 | 69 | 74 | 66 | 80 | 8.5 - 200 | 41 | 15.4 | 45 | 12 |
| Strontium | 82 | 213 | 74 | 144 | 81 | 43 - 930 | 200 | | 330 | 760 |
| Barium | 187 | 245 | 246 | 199 | 372 | 200 - 1700 | 580 | | 820 | 690 |
| Lead | 11 | 10 | 18 | 13 | 20 | 5.2 - 55 | 17 | 16.6 | 20 | 10 |
| Vanadium | 93 | 90 | 97 | 72 | 105 | 18 - 270 | 70 | | 55 | 28 |

Comparison data:

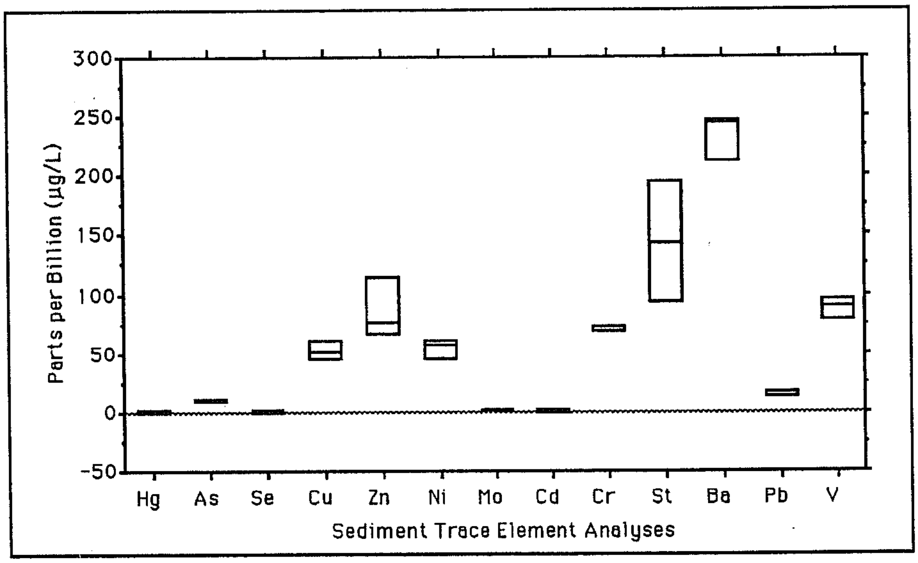
Gray Lodge: mean of 3 composite samples, Gray Lodge Wildlife Management Area, Butte Basin, California (Grewell, 1989).
Baseline Range (expected 95 percentile), Western U.S.: (Shacklette, et al., 1984).
BGM = Baseline Geometric Mean, Western U.S. (Shacklette, et al., 1984).
CA Mean = California Background Mean (University Of California, Davis, 1984).
KR2: Kesterson Reservoir, Pond 2 , May 1985 sediment analysis.
TLDD-S: Tulare Lake Drainage District South evaporation basin, November 1987 sediment analysis (Fujii, 1988).

Site Index:

S1 Logan Creek (Background, Above irrigated agriculture)
S2 North Fork Logan Creek (North) at west refuge boundary
S3 Area Agricultural Drain/South of Logandale at west refuge boundary
S4 Logan Creek at west refuge boundary

Table 12. Descriptive statistics of sediment trace element data.

| Statistics | Copper | Zinc | Vanadium | Nickel | Arsenic | Chromium | Strontium | Barium | Lead | Selenium |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 52 | 88 | 86 | 53 | 10 | 70 | 144 | 230 | 14 | 0.53 |
| Stand. Deviation | 12.5 | 34.8 | 12.9 | 11.5 | 2.7 | 4 | 69.5 | 26.8 | 4 | 0.25 |
| Standard Error | 7.2 | 20.1 | 7.4 | 6.4 | 1.6 | 2.3 | 40.1 | 15.5 | 2.3 | 0.14 |
| Variance | 156.3 | 1213 | 166.3 | 124.3 | 7.4 | 16.3 | 4830.3 | 721 | 16.3 | 0.06 |
| Coeff. Var. | 23.9 | 39.6 | 14.9 | 21.2 | 27.9 | 5.8 | 48.3 | 11.7 | 29.5 | 46.2 |
| Count | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Minimum | 40 | 60 | 72 | 40 | 7.2 | 66 | 74 | 199 | 10 | 0.25 |
| Maximum | 65 | 127 | 97 | 61 | 12.6 | 74 | 213 | 246 | 18 | 0.7 |
| Range | 25 | 67 | 25 | 21 | 5.4 | 8 | 139 | 47 | 8 | 0.45 |
| Geometric Mean | 51 | 84 | 86 | 52 | 10 | 70 | 131 | 229 | 13.3 | 0.49 |




Explanation: Boxes represent the range of the data.

Figure 9. Boxplots of Total Recoverable Sediment Trace Element Concentrations.

on Irrigation Drainage has developed guidelines to assist study teams in comparing data to these background levels (Wells, et al., 1988). The geochemical baselines have been developed from soil data and can only be compared to sediment data and serve as an indicator of uncommonly high or low trace element concentrations. The data was also compared to mean background levels of heavy metals in selected California soils (University of California, Davis, 1984), and to trace element concentrations in sediment collected approximately 25 miles southeast of the refuge at Gray Lodge Wildlife Management Area (Grewell, 1989).

Table 11 also lists a summary of bottom-sediment trace element concentrations from Kesterson Reservoir and Tulare Lake Drainage District's south agricultural drainage evaporation basin. These extreme examples are sites where agricultural drainage has been associated with documented impairments to wildlife populations and are included only for comparative purposes.

The selenium content of the bottom sediment of these composites ranged from 0.25 - 0.70 µg/L that falls within the baseline range selenium concentration of 0.039 - 1.4 µg/L, and is well below the 4.0 µg/L cleanup level which was established for Kesterson Reservoir sediment. Mercury was detected in one sample (North Fork Logan Creek) at a natural background level. Arsenic, copper, zinc, nickel, molybdenum, chromium, strontium, barium, lead, and vanadium were all present in the samples at level within the natural background baseline range. Cadmium was not detected in any of the samples.

Arsenic was detected at 15.50 µg/L in sediment at the background site in the upper reaches of Logan Creek. The samples sites within the drains carrying agricultural drainwater showed lower arsenic levels at 7.20 - 12.60 µg/L. Copper was present at 45 µg/L in the Logan Creek background sediment. Copper compounds are used extensively as algacides and for the control of tadpole shrimp in rice fields. The agricultural drain sampling sites averaged 53 µg/L copper, which is elevated above the background 15 µg/L mean for California soils, but is only slightly higher than the copper concentration measured in the upper watershed sediment, and nearly identical to the 54 µg/L mean copper concentration in rice drain sediment at Gray Lodge Wildlife Management Area. Vanadium concentration in the upper reach of Logan Creek was similiar to the sites which carry agricultural drainage. Vanadium concentration averaged 86 µg/L in the sites at the refuge boundary, and 93 µg/L at the background site in Logan Creek above all irrigated agriculture.

Zinc, nickel, molybdenum, chromium, strontium, barium, and lead concentrations were all detected at refuge boundary sediment sample sites above the levels measured at the Logan Creek background site. However, all of these trace elements were measured within the expected geochemical baseline ranges for the western United States. Nickel concentrations in sediment collected from rice drains at Gray Lodge Wildlife Management Area averaged 76 µg/L which is elevated with respect to the expected baseline of 3 - 66 µg/L. However, normal nickel levels were observed at Sacramento NWR as background sediment averaged 38 µg/L and rice drain sediments averaged 53 µg/L.

As lead concentrations were recorded above the protection criterion in the Logan Creek water samples, it should be noted that lead concentrations in the sediment samples at the refuge boundary averaged 14 µg/L at the drain sites and 11 µg/L at the background site. These measurements are below the 17 µg/L average for California soils.

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